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MINING METHODS OF THE DUCKTOWN CHEMICAL AND IRON CO., MARY MINE, ISABELLA, TENN.

BY

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MINING METHODS OF THE DUCKTOWN CHEMICAL AND IRON CO., MARY MINE, ISABELLA, TENN.[1]

By Vern L. Kegler[2]

INTRODUCTION

This paper is one of a series dealing with mining methods and costs, sponsored and published by the United States Bureau of Mines.

ACKNOWLEDGMENTS

The author acknowledges the constructive and helpful suggestions and criticism of W. F. Lamoreaux, vice-president and general manager of the Ducktown Chemical & Iron Co. United States Geological Survey Professional Paper 139, by W. H. Emmons and F. B. Laney, has been drawn upon for some of the information contained in the paragraphs on history and geology.

HISTORY

The Mary mine was first opened in September, 1853. It was mined for black copper ore by various companies and interests, but principally by the Union Consolidated Co., which was organized in 1858. The lower-grade primary ores were first mined and concentrated about 1870. Due to dissention among the operators, however, the mine was shut down in 1879. In 1890 the Ducktown Sulphur, Copper, and Iron Co., Ltd., a British organization, reopened the Mary mine and began producing the lower-grade primary ore, smelting it at Isabella. This company operated the Mary mine continuously until 1925, when the present company obtained control.

GEOLOGY AND CHARACTER OF ORE BODIES

General geology

The ore occurs in lenses replacing certain folded and faulted beds in highly metamorphosed sediments of the Great Smoky formation of lower Cambrian System. These sediments consist in the main of graywacke with arkose, graywacke conglomerate, mica schist, slate, staurolite schist, and garnet schist.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6397."

[2] One of the consulting engineers, U. S. Bureau of Mines; and superintendent of mines, Ducktown Chemical & Iron Co.

The shape of the ore bodies is controlled largely by the folding of the country rocks, which characteristically exhibit swells on the crests of anticlines and domes, and pinches on the flanks of the structure. Post-mineral faulting has complicated the structure by displacing the ore bodies, causing repetition of the swells and pinches within short distances. The predominant faults trend northeast and southwest, paralleling the strike of the ore bodies, but transverse faults also occur.

The ore bodies have a general strike of N. 45°E. and a dip of 65° to the southeastward.

The Mary ore body is approximately 2,000 feet long and varies in thickness from a few feet to 150 feet. The ore body as developed and mined has followed an irregular course and is composed of several distinct parts, more or less connected by small blocks of ore which represent the drag of the blocks produced by the post-mineral faulting. See Figure 1, which shows a plan of the ore body and Figure 2 which shows vertical sections.

The wall rocks are composed of Mica schists and graywacke and stand well in spans of 100 feet. In some places in the mine there are spans of 150 feet. Occasional difficulty is experienced with falling rock when the wall rocks have been fractured by faulting or where the wall has been broken during mining operations. Where the contact between ore and wall is sharply defined, care must be taken to avoid breaking the wall so as to start it ravelling. In some places the contact between wall and ore is not sharply defined and a wide area of gangue or low-grade ore takes the place of the schist as the hanging wall. These areas, as a rule, stand well when unsupported. The wall rocks break along the bedding planes and planes of schistosity.

The ore stands well when broken in the form of an arch. If arching is not done during mining the ore tends to arch itself. An attempt is made in all operations to arch the span of the backs of the workings.

The ore having amphibole as the principal gangue mineral stands better than ore with quartz as the principal gangue mineral. Numerous slips and joints are found in the ore, the direction of the most pronounced planes being normal to the dip.

Careful inspection of the backs of all workings is necessary and a special crew of "baulk ground" men is necessary to reduce the hazard of falling rock.

Very little timbering is used in the mine, other than in the shaft. Some timbering is necessary at the shaft stations where the span in flat-lying schist requires additional support.

The ore is composed of pyrrhotite and chalcopyrite as the principal ore minerals, with sphalerite and galena as accessory ore minerals. The gangue consists of quartz, amphibole (actinolite), and diopside as the principal gangue minerals, with dolomite, calcite, zoisite, epidote and garnet as the accessory gangue minerals. The amount of the gangue minerals actinolite and diopside present in the ore influences to a large extent the breaking quality and the ability to stand unsupported. Where the ore contains small amounts of these gangue minerals the shattering qualities are good, but if the reverse is true, considerable difficulty is encountered in blasting operations, and the rock will stand well when unsupported.

The upper portions of the ore bodies contain large amounts of quartz, which diminishes with depth. The lower portions of the ore body contain large amounts of actinolite. In general the ore becomes more siliceous with depth at the expense of the sulphides.

Due to the large amount of faulting which has dislocated the original ore body, sharp changes in values occur throughout the mine.

PROSPECTING AND EXPLORATION

The prospecting of the Mary ore body was originally done by the early miners who mined out the zone of enrichment. The general method was to first bare the outcrop by "costeaning" or trenching both across and along the strike of the vein. Following this operation, test pits or small shafts were sunk to the zone of secondary enrichment, the depth varying from 50 to 150 feet below the surface. The black copper ore, principally chalcocite, was then mined. These workings traced out the outcrops of all of the principal ore bodies known to-day; in fact, no discoveries of large ore bodies have been made in recent years.

Due to the great irregularity of the ore body and the uncertainty regarding its continuity, the exploration drifting is for the greater part confined to the ore showings. The exploration drifts have in most cases been utilized as main haulage drifts after stoping operations have been started. Where the showing of ore does not warrant drifting, diamond drilling is resorted to in most cases. The walls are tested to a depth of 300 feet by horizontal diamond drill holes, spaced at regular intervals along the strike of the ore body. Permanent records are kept of the cores and the assays of samples taken therefrom.

SAMPLING

In the Mary mine ring samples are taken in all drifts and raises at intervals of 5 feet along the course of the drift or raise without regard to the strike or dip of the vein. These ring samples are taken on the ribs and backs of the workings by chipping small pieces every few inches around the circumference of the drift or raise. These samples have been found to be as accurate as samples taken by channeling, either by machine or by hand. A 15-pound sample is taken. The samples are numbered consecutively, and the location is plotted on an assay map of the workings. The assays are recorded on a separate assay sheet.

A small grab sample is taken of each mine car loaded, and the sample is deposited in an iron box or can provided for the purpose at each tramming place. These samples are collected twice each week and the tonnages and values of the ore extracted from each stope are calculated. A careful record is made of all ore extracted. A grab sample is taken once each week of all working faces as a guide or check in breaking the ore. The grab samples of the mine run to the smelter and to the mill are taken after the ore has passed through the primary and secondary crushers.

CHAMBER-AND-PILLAR SYSTEM

After exploration has defined the strike of the ore body, it is divided in plan into chambers 60 feet wide and pillars 40 feet wide, as measured along the strike of the ore body. These chamber-and-pillar reservations are projected vertically through the ore body to include all levels. The stoping operations are confined to the chamber until the chamber area has been extracted. When a series of chambers has been mined out, small areas are cut out of the pillars between the levels and the chambers are thus connected. The floors are then extracted by underhanding, and finally the pillars at the levels are trimmed to the minimum size necessary to support the walls. In all these operations the spans of ore and wall rock are arched to minimize the hazard of falling ground.

METHODS OF DEVELOPMENT AND MINING

Vertical hoisting shafts are used throughout the ore body. The ore body is usually explored by winzes, either vertical or inclined, or by diamond drilling prior to the shaft sinking. There are three principal shafts, only one of which, the Gordon Shaft, is now in use as a hoisting shaft. Haulage levels are driven through the wall rock to the ore body where drifting follows the hanging wall, in ore, in order to provide ample room for the tramming chambers at the footwall. Crosscuts are driven from hanging to foot wall. In recent years the drifting has followed the center of the vein rather than the hanging wall, less space being required for the chutes and grizzlies. The development in all cases is in ore, except where it is necessary to pass through wall rock to reach the vein. The haulage levels driven in wall rock from the shaft to the vein in some places pass through the hanging wall and in others through the footwall. This is due to the irregularity of the ore bodies and the large amounts of displacement of the vein. Inasmuch as no caving is done during mining, those shafts which are in the hanging wall are not disturbed (see fig. 1). The level interval is 100 feet on the upper levels and 150 feet on the lower levels. Raises are driven in the chambers, near the footwall, to the level above. An offset is made in the raise 30 feet below the upper level to facilitate stoping and the use of the upper 30 feet as a manway.

DEVELOPMENT DETAILS

Shafts

Shafts of full size, 8 by 15 feet, are sunk vertically. No timbering is done between levels until the sinking has been completed. In some cases a pilot winze is put down at some distance from the shaft, and the shaft is then made by raising. This is only done where sublevel exploration workings are available. The drilling is done with heavy-type jackhammers, unmounted, using 7/8 inch hexagon steel and four-point, double-taper cross bit. Wet drilling is done in most cases. A sumping type round is used. (See fig. 3 showing typical shaft sinking round.) The explosives used is 40 per cent special gelatin dynamite and is fired electrically. Mucking is by hand, and a sinking bucket is used for hoisting the muck to the level above. The cycle of operations commonly used is to drill and blast during the first period, clear the face of smoke in the second period, and muck during

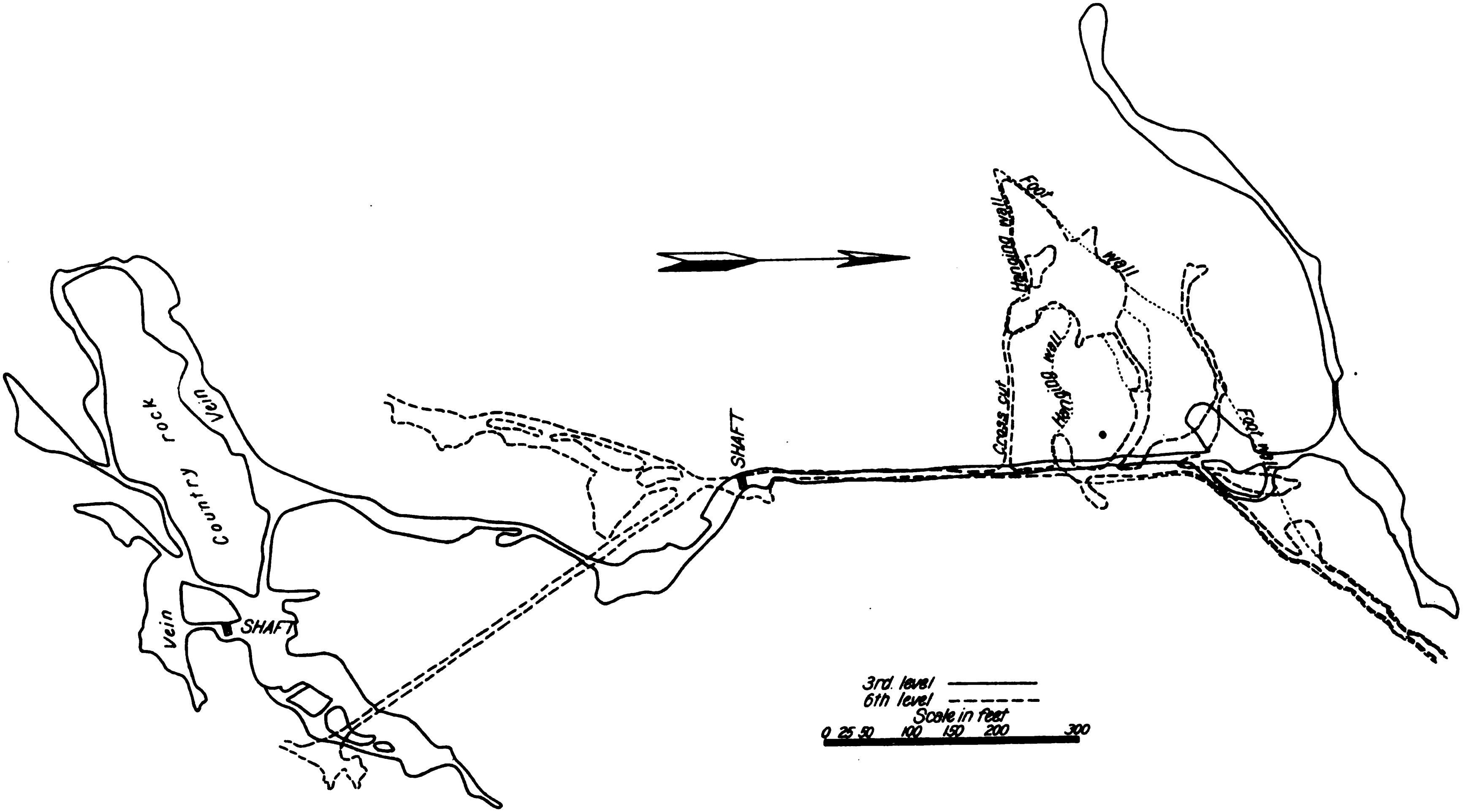


Figure 1.- Map showing ore bodies and connecting drifts on two levels Mary, mine

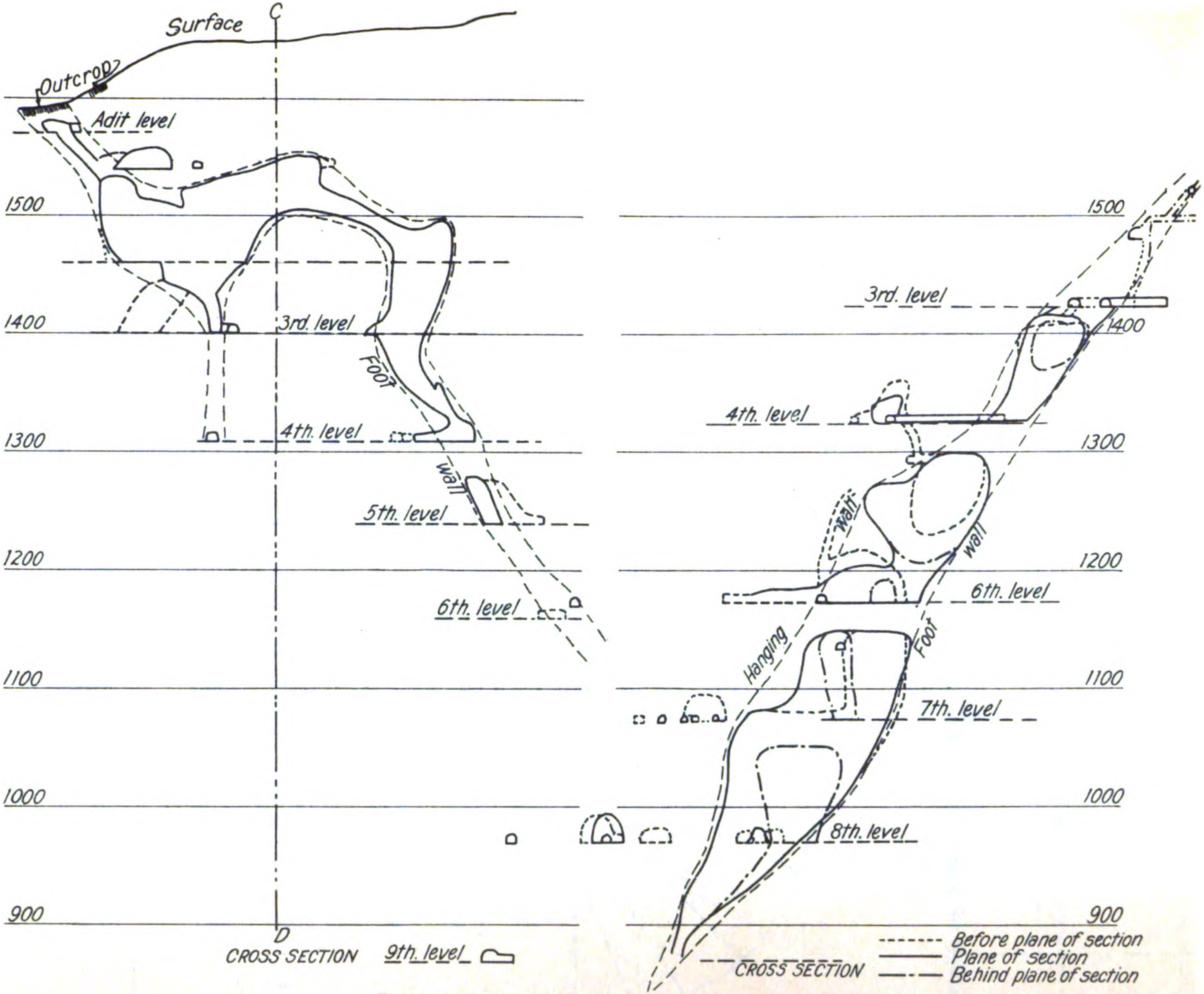


Figure 2.-Typical vertical sections Mary, mine

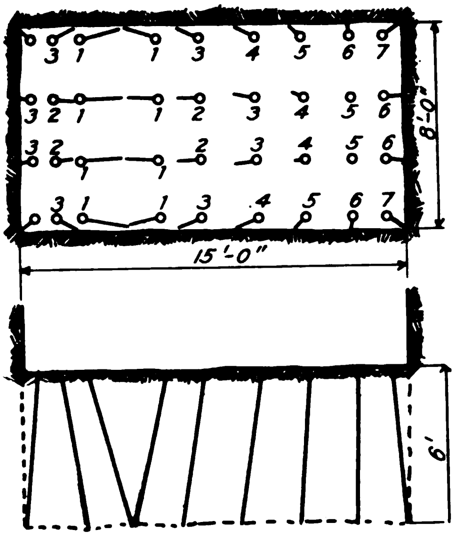
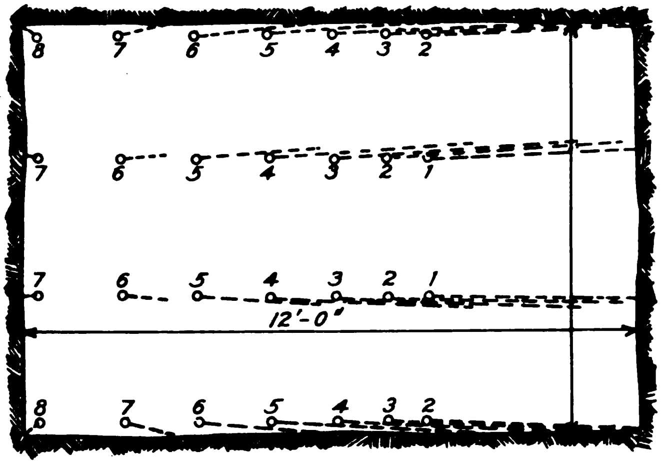
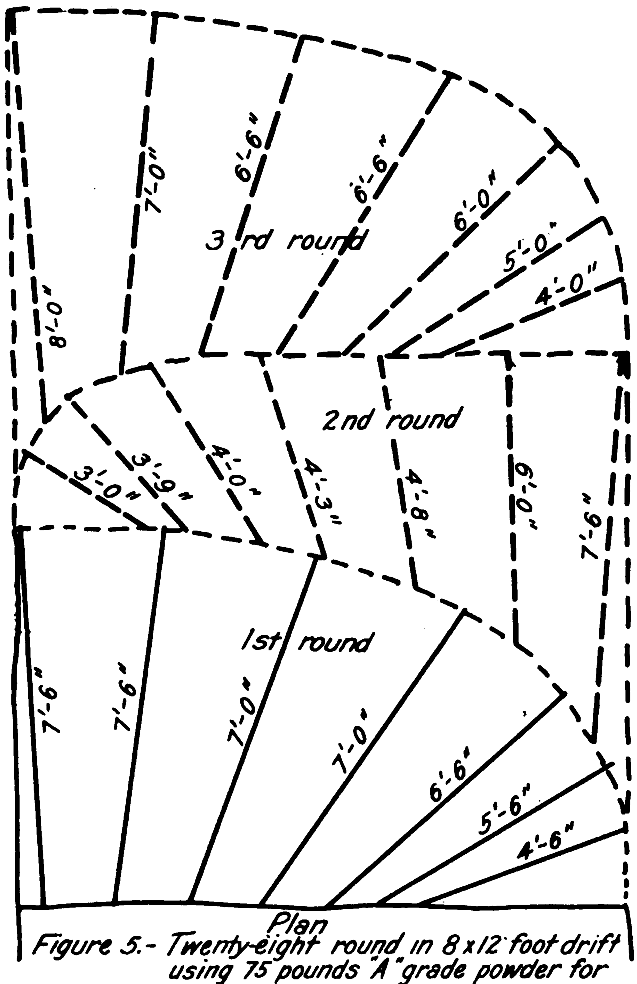


Figure 3.- Typical shaft round; numbers show order of firing



Elevation first round



Plan

Figure 5.- Twenty-eight round in 8 x 12 foot drift using 75 pounds "A" grade powder for 4-foot average advance

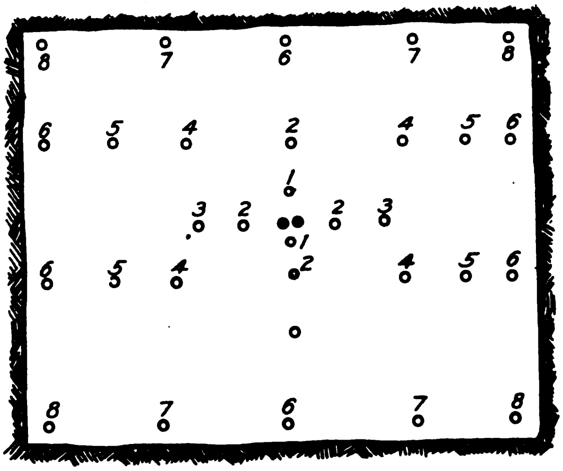


Figure 4.- Burnt-cut round in 8 by 10 foot drift; 6-foot holes using 110 pounds "A" grade explosive for 5½ foot advance

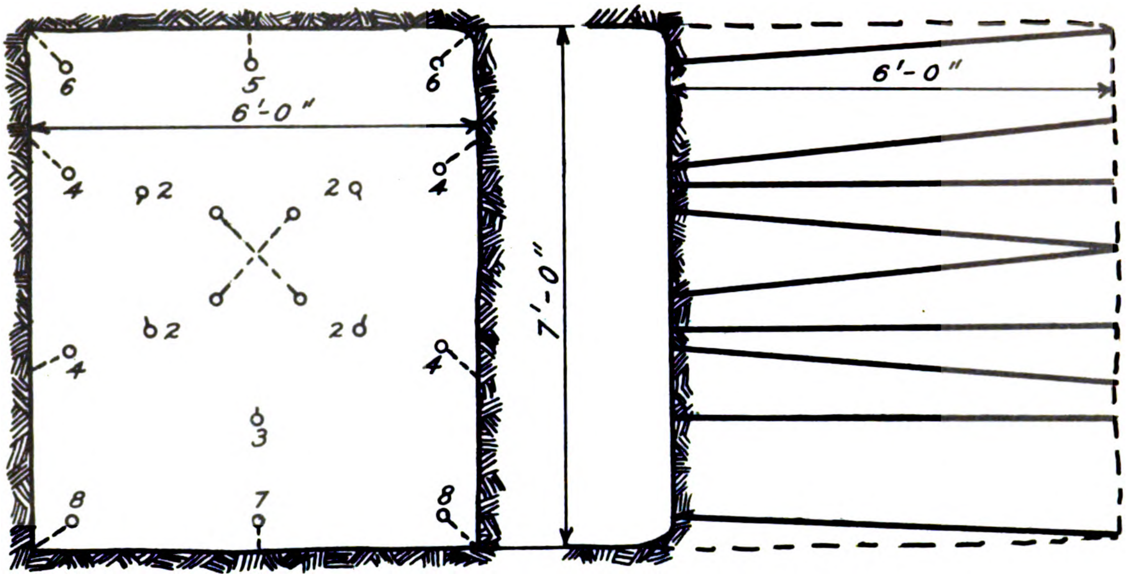


Figure 6.- Nineteen-hole round in 6 by 7 foot drift using 65 pounds "A" grade powder for 5 foot advance

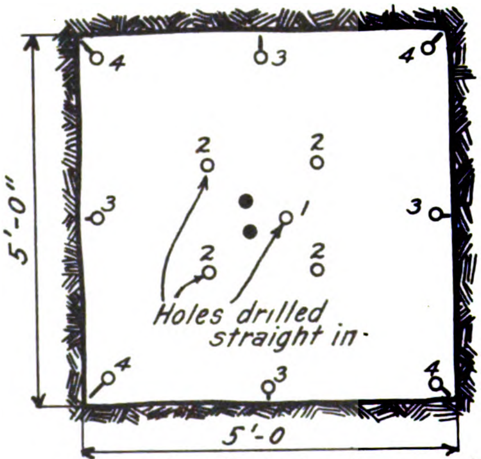


Figure 7.- Typical raise round drilled 6 feet deep, using burnout cut

the third period. These periods sometimes overlap, but the whole operation of advancing a round is accomplished in 24 hours. The progress made averages 3.5 feet per day. The shaft when completed measures 7 by 12 feet inside the timbering. Two compartments are used for operating 4-ton skips in balance, and a third compartment is used for a ladderway, pipes, and power cables.

Drifting

The main haulageways are driven 8 by 10 feet in cross section. No timbering is used for support. Drilling is done with two mounted heavy-type drifter drills using 1¼-inch hollow drill steel. The crew consists of two drillers and a helper. The contract price is $8 per foot.

The contractor pays for all labor and explosives. A 33-hole round is generally used, but occasionally a 28-hole round is used. (Figs. 4 and 5.) The slabbing round has given the better results, requiring less drilling and explosive Drilling and blasting is done on the first shift and is followed by mucking on the second shift. The average rate of advance is one round, or 4.5 feet per day of two 8-hour shifts.

Ammonia dynamite explosive is used in this work, and approximately 2.5 pounds of explosive is used per ton obtained from the headings.

Mucking is done by hand by a three-man crew who are paid 17 cents per ton per man. No mechanical loading is used.

Raises

The raises measure 5 by 5 feet and are advanced at a rate of one heading o 5 feet advance per shift. Hand-rotated wet stopers are used; the drill steel is 1-inch hollow hexagon steel with a 4-point, double taper bit. A typical round is shown in Figure 7. Forty-five pounds of ammonia dynamite is used per round, breaking 5 feet per round.

Mining

The method of mining used at Mary mine is that of open stopes with regular pillar support (fig. 8). Underhand stoping has been used in practically all of the mining completed to date. Some open breast-stoping was done in places where the ore bodies extended but a few feet above the level. Excellent support of the walls and back was achieved by cutting irregular pillars, and an effort was made to leave the lower grades of ore in these pillars, which for the most part was successful. In order to obtain the best recovery of the high-grade ore a thorough knowledge of the distribution of values in the ore body would seem essential; however, it is striking that the amount of development done prior to stoping operations was comparatively small, and that the distribution of low-grade values in pillars was made during the stoping operations. No caving is done in these operations. At present the northern ore body is in the process of being robbed by firs removing the outlying portions and then the central portion lying nearest the shaf Sufficient pillar support is being left to prevent surface subsidence.

After any part of the ore body is explored by drifting or diamond drilling, the exploration drift is made the haulageway, and a crosscut is driven in the chamber to the footwall. The crosscut is then slabbed to a horizontal width of 14 feet to provide a tramming station. A plank floor or sollar is laid and raising is then started to the level above. Upon completion the raise is reamed to a diameter of 10 feet, from the floor pillar of the level above to the level below. Stoping is then started at the top of this reamed raise by cutting a bench around the raise. Benches are then carried down through the stope by underhanding. When the slopes of the stope become steep and access to the benches is difficult, new benches are cut at the top. The chief disadvantages of this method are the amount of mucking required to clear a bench for drilling, and the hazard of working under a high, wide back.

The broken muck is loaded by hand into 1-ton mine cars and trammed to the shaft by hand.

In recent years several types of grizzlies at the level and of sub-level grizzlies with chutes have been constructed to eliminate hand-loading. The loading of muck in the tramming stations is particularly dangerous because of running muck piles and scales of rock falling from benches or the backs of the stopes.

DRILLS AND DRILL STEEL

Four types of drills are used: Heavy and light drifters, hand-rotated stopers, and heavy-type jackhammers. All drilling is wet. Card records are maintained in the drill repair shop, showing the driller to whom the drill was issued and a list of all other equipment for which he is responsible. Another card record is maintained which shows the time in and out of service, the dates of inspection, and the details of repairs made to each drill. Drills are inspected once each month, regardless of whether repairs are necessary. Line oilers are used on all air-operated machines, including hoists and diamond drills. Stocks of drill parts are kept to the minimum by keeping extra drills on hand; this likewise minimizes the delay to the driller.

The drill steel used consists of three sizes, 7/8 inch hollow hexagon, 1-inch hollow hexagon, and $1\frac{1}{4}$-inch hollow round, the standard run of steel is from 2 feet to 10 feet. Special runs are available for drilling test holes to a depth of 20 feet. The double-taper, four-point cross bit is used on all steel. A change of 1/8 inch in gage is made every 2 feet. A single sharpener supplies drill steel for the mine. Steel racks for sharp and dull steel are provided in the shop and on each level underground. As much sharp steel is held in stock as is in circulation in the mine. Oil furnaces are used for forging and tempering heats. A pyrometer controls the maximum forging heat, and a magnetic indicator controls the minimum tempering heat. A daily record is maintained of steel breakage which is summarized monthly.

WAGE SYSTEMS EMPLOYED

For many years the practice at this mine has been to pay the crews of drillers or contractors on the basis of cars of ore broken in the stopes, payment being made on the number of cars trammed. Each crew of contractors usually consists of two drillers who are paid 15, 20 or 25 cents per car (1 ton), of ore delivered to the level, depending on the character of the ore, the size of the stope, and level interval of the stope. The contractor pays for additional labor needed and for explosives. This is a good method for obtaining large tonnages of ore, but there are several disadvantages in this method, as follows:

a. The tendency to break large muck rather than small, for tonnage, thus increasing the cost of secondary breaking or blocking and the costs of transportation due to the delays.

b. The incentive to break waste with ore.

c. The cultivation of poor methods of breaking, to the advantage of the contractor and the disadvantage of the company.

d. Lack of flexibility in moving the contractors from one stope to another because of stocks of broken ore and stope development, such as roadways and benches which have been completed.

e. The practical impossibility of making contracts to suit all of the varying conditions found in an ore body irregular in shape, size, and character of ore.

f. The large amount of supervision necessary to combat the disadvantages mentioned.

This mining method seems well adapted to small deposits. The advantages of it are as follows:

a. The small amount of development required to make available large tonnages of ore.

b. The advantage of having small tonnages produced from several stopes and thus provide more uniformity in the grade of ore produced, particularly in deposits in which the grade varies considerably in short distances.

c. The advantage of having the ore body thoroughly explored and developed for stoping before the mining operations have reached advanced stages.

The disadvantages are:

a. A higher operating cost and lower efficiency.

b. Small production per stope.

c. Hazardous stoping operations.

TABLE 1.- Summary of Costs

Mary mine Year of 1928

Tons ore mined and hoisted: 108,519 (short tons).

Mining method: Open stopes with pillar support. Robbing operations.

Underground costs per ton ore hoisted

	1 Labor	2 Super-vision	3 Comp. air drills and steel	4 Power cost	5 Explo-sives	6 Other sup-plies	7 Total
Development	.215	.020	.054	- -	.066	- -	.355
Mining: Stoping and block holing	.270	.022	.177	- -	.076	- -	.545
Hand mucking and tramming	.319	.026	- -	- -	- -	- -	.345
Underground transportation[1]	.159	.014	- -	.196	- -	- -	.369
General[2]	.079	.005	- -	.020	- -	.050	.154
Surface	.040	- -	- -	- -	- -	.020	.060
Total	1.082	.087	.231	.216	.142	.070	1.828

[1] Includes track and car maintenance and hoisting.

[2] Includes pumping expense, baulkers, etc.

TABLE 2.- Summary of costs in units of labor, power, and supplies

Mary mine — Year of 1928

Tons ore mined and hoisted: 108,519 (short tons).

Mining method: Open stopes with pillar support. Irregular pillars left from regular pillar and chamber plan. Robbing operations.

	Development	Mining (stoping)	Total
Tons ore produced	8,968	99,551	108,519
A. Labor (man-hours per ton):	(1)	(2)	(3)
Breaking	1.657	.426	.530
Blocking	- -	.130	.119
Mucking and tramming ...	2.026	.622	.738
Hoisting	- -	.576	.528
General	- -	.241	.222
Supervision	- -	.105	.096
Total (man-hours per ton)	3.683	2.100	2.233
Average tons per man-shift	2.168	3.808	3.582
Labor, per cent of total cost			59.2%
Average tons per man shift on surface properly chargeable to underground operation...			12.65
B. Power and supplies:			
Explosives (lbs. per ton).....	4.806	0.420	0.782
Grade	40%	40%	40%
Total power (in kw.h. per ton)			10.50
(lbs. coal per ton)			81.10
1. Air compression (kw.h. per ton)			8.75
2. Hoisting (lbs. coal per ton)			81.10
3. Pumping (kw.h. per ton)			1.75
Supplies and power, per cent of total cost			40.8%
C. Per cent of total cost	19.4%	80.6%	100.0%

(1) Based on tons produced from development work. (2) Based on tons produced from stopes. (3) Based on total tons mined and hoisted.

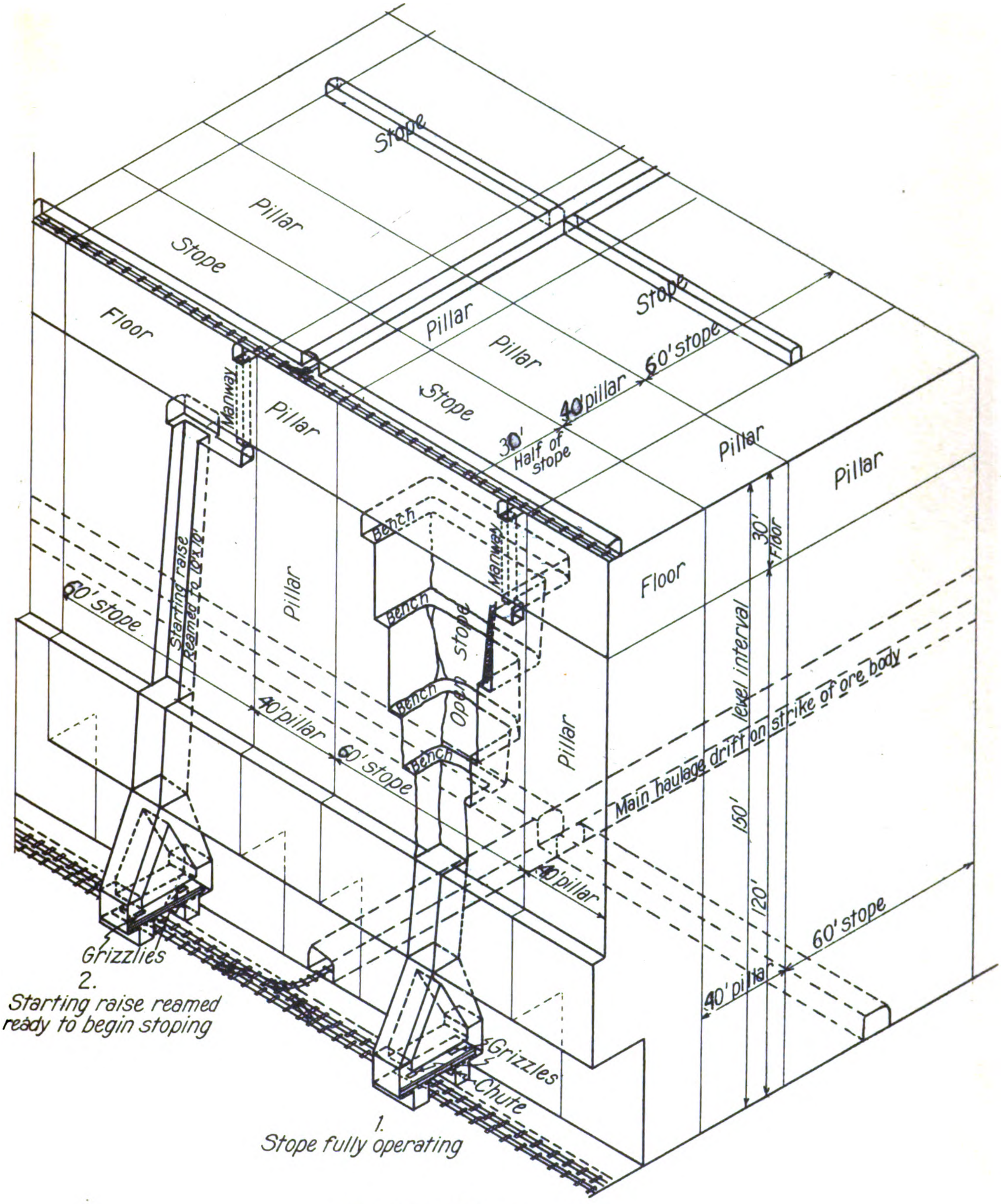


Figure 8.- Stoping method